Status of LLRF Technology at SPring-8

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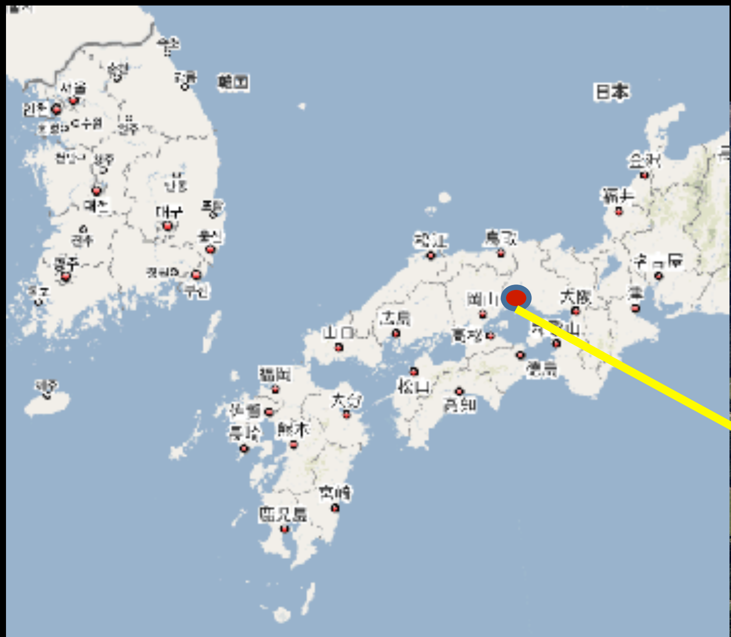
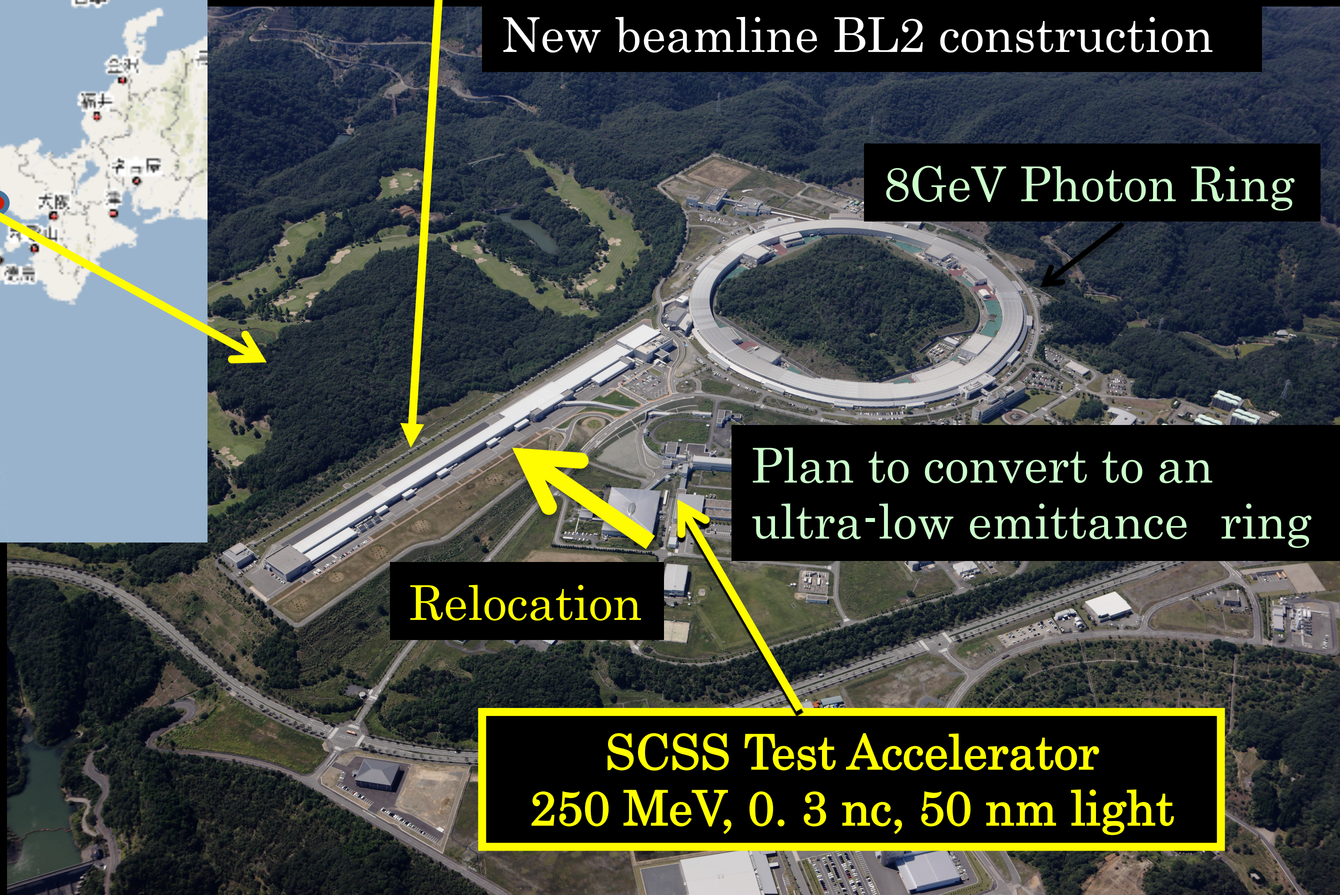
I would like to mainly talk about modifications of our present LLRF system based on the state of art technology motivated by the new accelerator construction plans at SPring-8.

New Project of SPring-8 Site





SPring-8 SACLA RIKEN JASRI

Modification Plans of Accelerators

Plan & construction of new accelerators & beamlines

- Plan of an ultra-low emittance SR ring, we call it Spring-8-II aimed at a diffraction limitation.
- SCSS+ to emit EUV in the SACLA's building, which is relocated and modified form the present SCSS test accelerator.
- New X-ray beamline, BL2, at SACLA.

- This presentation mainly introduces modifications and improvements of LLRF systems related to SPring8-II, by way of example.

Tentative Parameters of Ultra-low emittance Ring at SPring-8

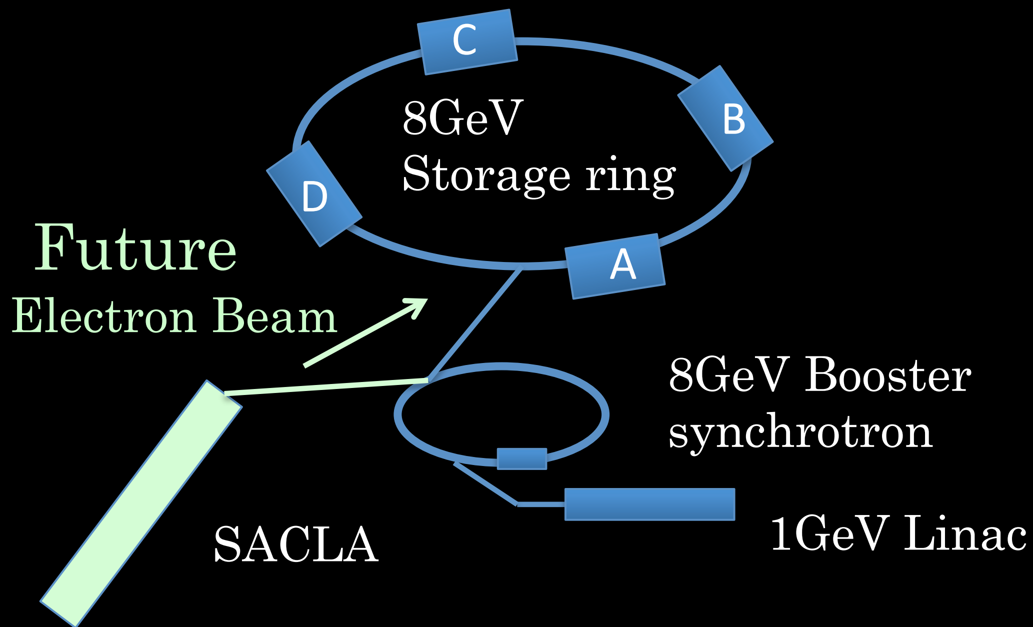
Beam Energy	6 GeV
Stored Current	~ 300 mA
Lattice	DBA x 2
Natural Emittance	274 pmrad
Tune (Q_x, Q_y)	118.82, 47.71
Momentum Compaction Factor	2.67 x 10^{-5}
RF Stations	4
Klystron RF Output Power	1 MW
RF Frequency	508 MHz

This will be changed by future design work.

Present RF system of SPring-8 Ring & Future

RF system of Spring-8 Storage Ring

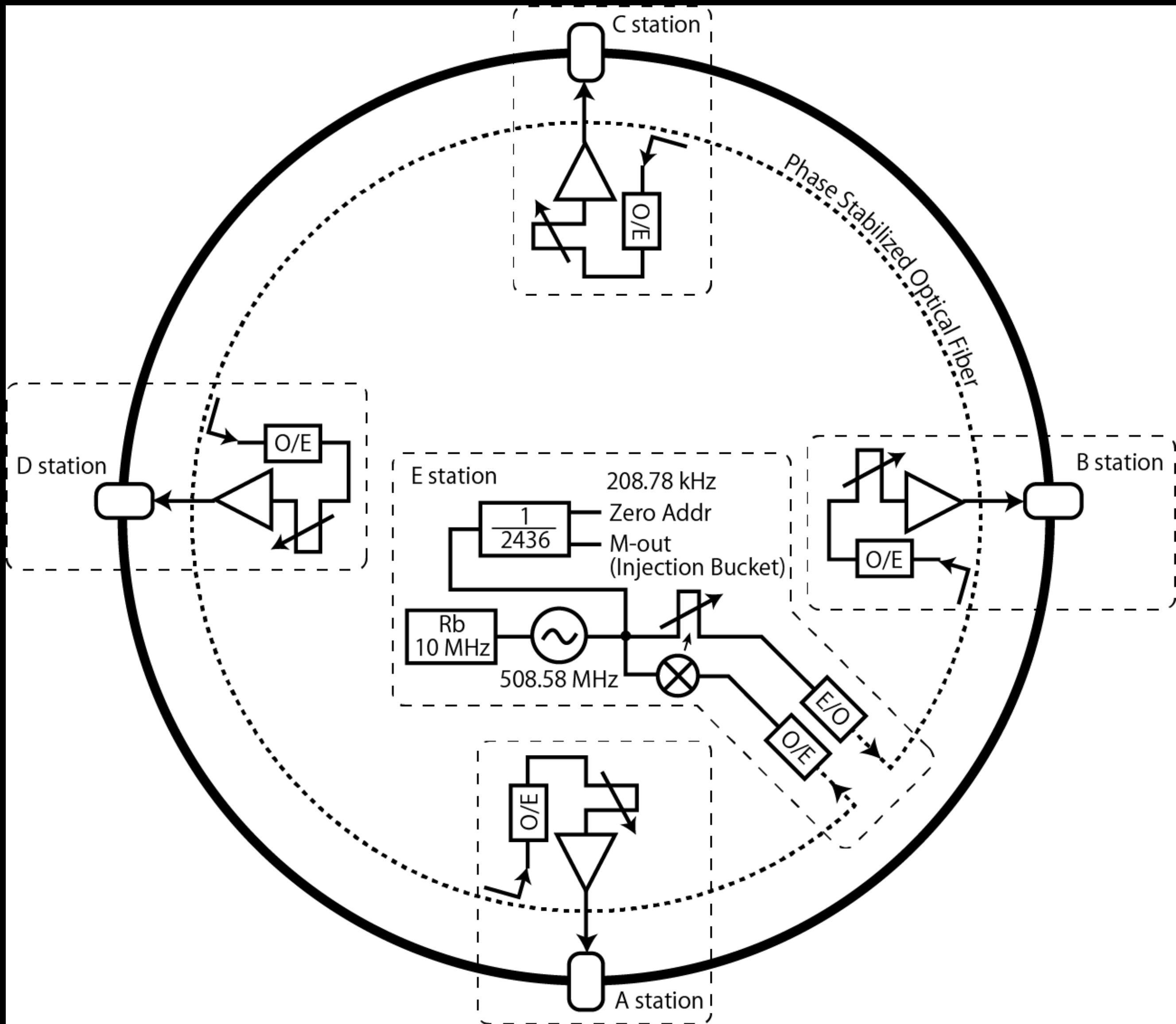
- Acceleration voltage : ~ 12 MV
- Energy loss per turn : ~ 10MeV
- Stored current : ~ 100mA
- Frequency: 508.58MHz
- 4 RF stations
- 8 single-cell cavities / station
- Full energy injection (Top-up operation)



1MW CW klystron

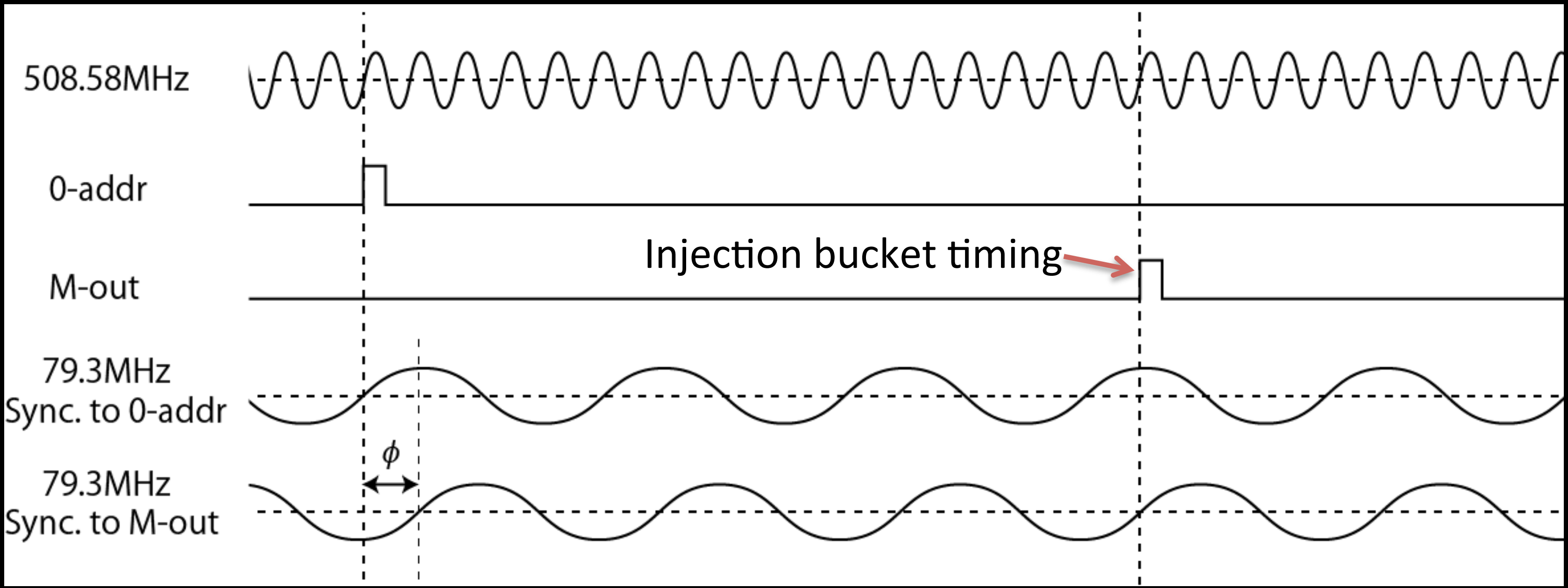
Acceleration cavities

RF & Timing Distribution in the SP8 SR



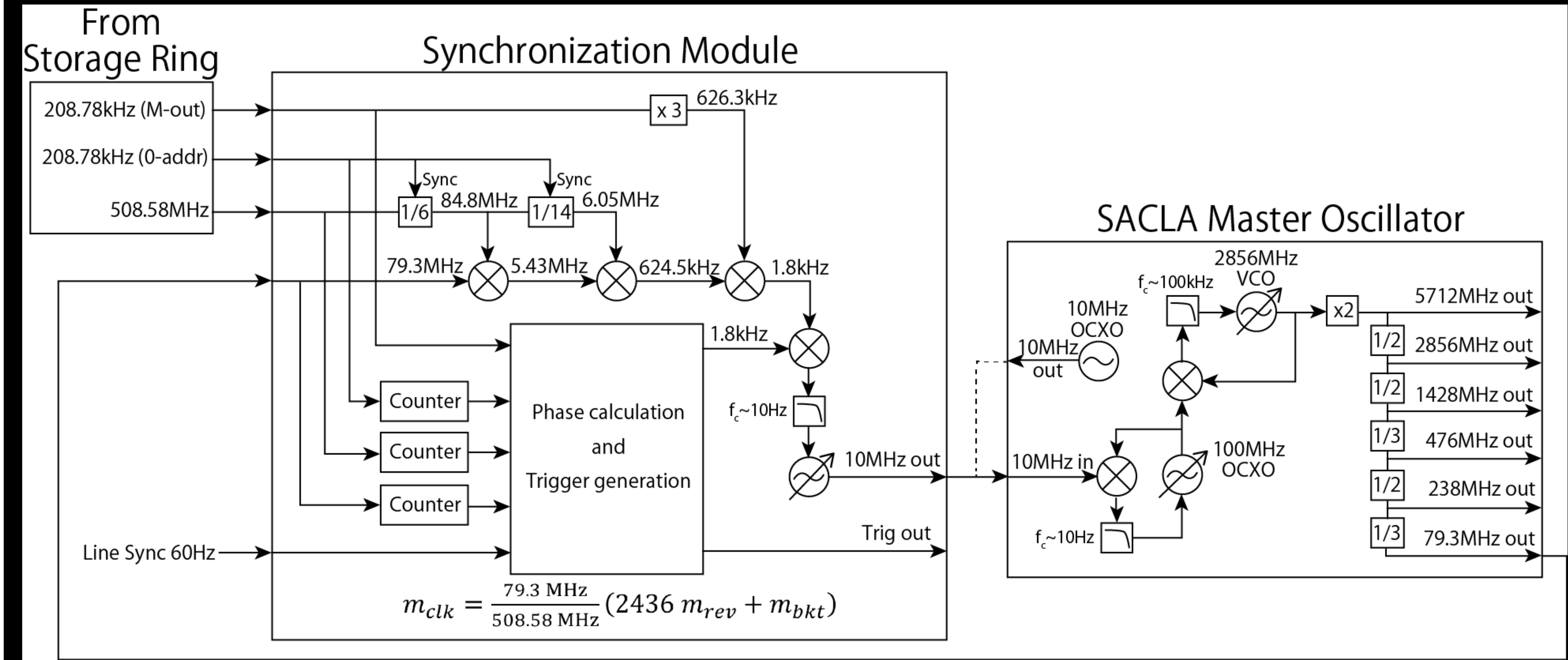
Timing Relationship between SP8 and SACLA

- SACLA Linac
  - Accelerator is driven by integer multiple of 79.3 MHz (79,333,320 Hz).
    - 5712MHz / 72 = 79.3 MHz
  - Trigger is also synchronized with the power line (60 Hz) and 5712 MHz.
- SPring-8 Storage Ring
  - Acceleration RF frequency is 508.58 MHz.
  - Revolution Frequency is 208.78 kHz.
    - 508.58 MHz / 2436 = 208.78 kHz
- Poor integer relationship between the RF frequencies of SP8 and SACLA
- The RF phase of SACLA has to be re-synchronized with SP8 at each injection.
- Required timing accuracy is 1 ps in rms.



Synchronization between SP8 and SACLA

- Produce the 1.8 kHz IF signal from the 508.58 MHz, 208.78 kHz, and 79.3 MHz signals.
- Generate the reference 1.8 kHz signal from injection timing information.
- Phase difference of these 1.8 kHz IF signals is fed into the frequency tuning port of a 10 MHz signal source in the SACLA master oscillator.



Phase Detection Method and Target Phase

- Phase Detection
  - By mixing 79.3 MHz and 208.78 kHz, we can get 1.8 kHz IF signal.
- Target Phase Calculation

  A: Number of 79.3 MHz clocks from the injection timing.

  B: Number of revolutions from the injection timing.

  C: Bucket number

  - Fractional portion of B divide by A corresponds to the target phase of 1.8 kHz IF signal. Then, from the portion and C, we can obtain optimum timing of the target bucket along the ring.

LLRF System for the Present SPring-8 Ring

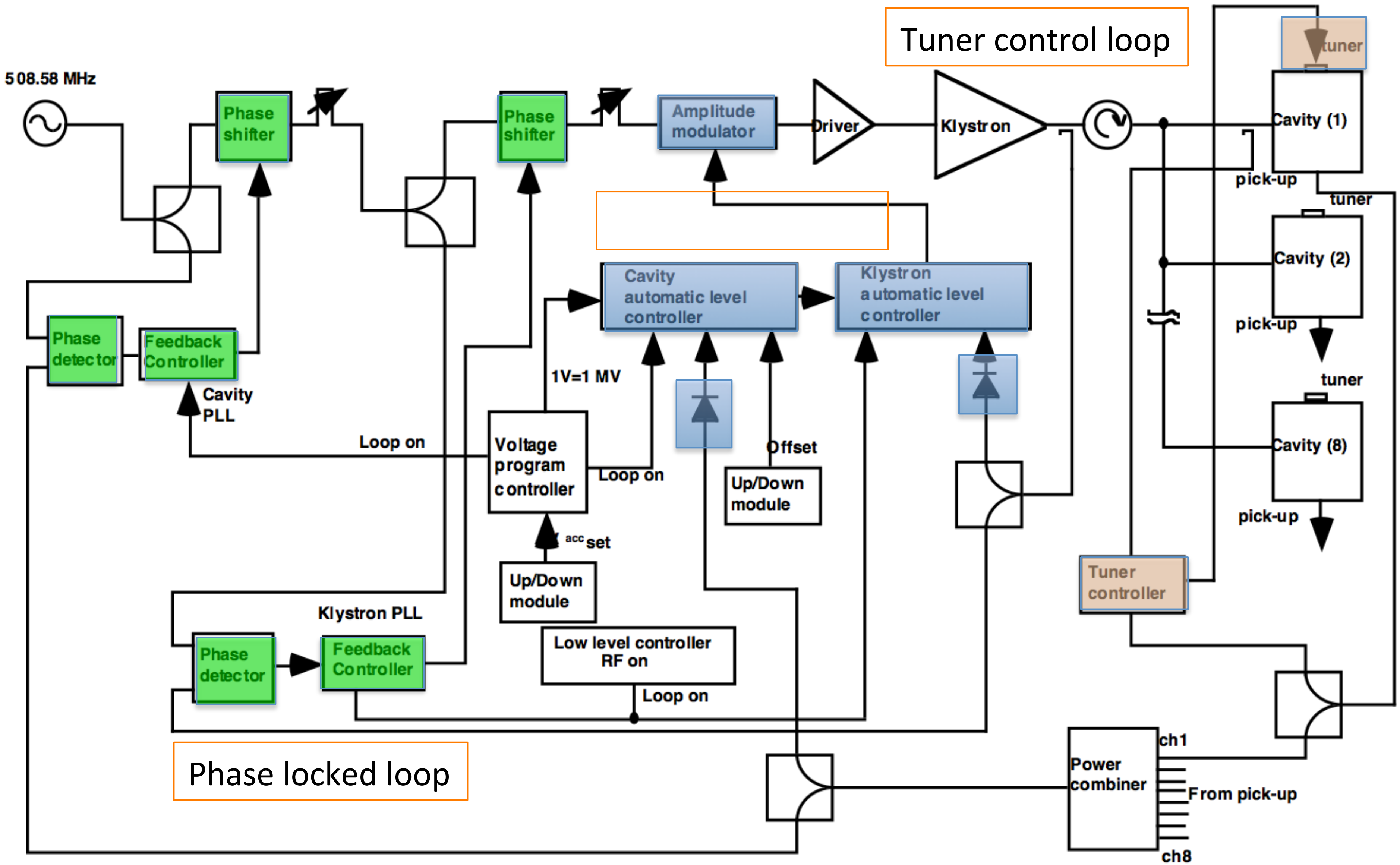
LLRF block diagram of SPring-8 Storage Ring

- Hardware：NIM based modules
- Control：VME modules
- Phase stability 0.01deg in rms
- Amplitude stability 1E-4 in rms

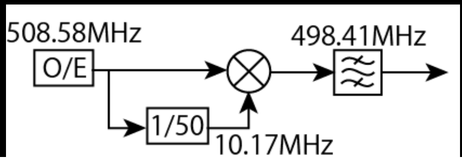
Almost fully analog control

Replace this analog control circuit to full digital circuits for Spring-8 II

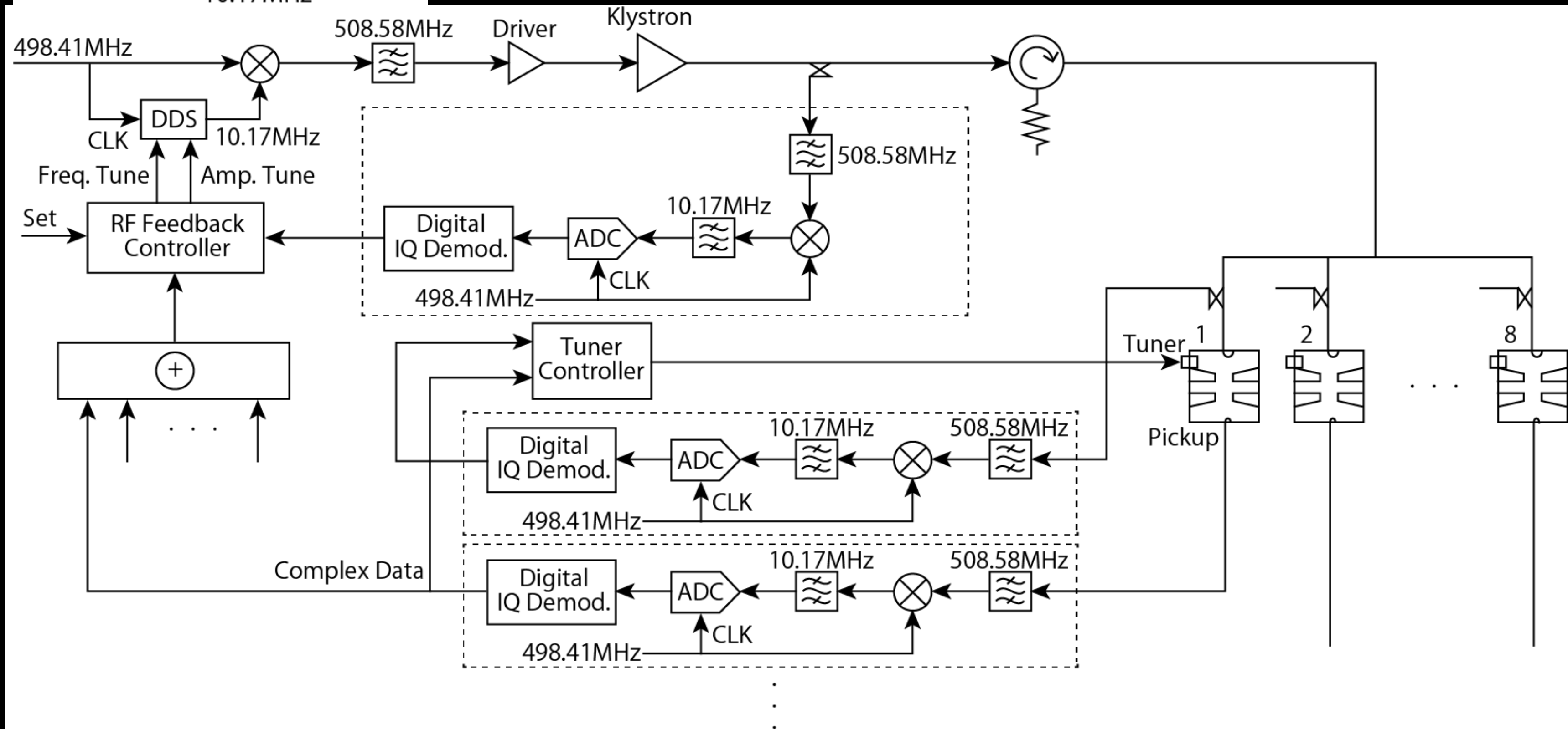
Block Diagram of LLRF System for Ring RF Station



Digital LLRF System Scheme for Spring-8 II



This digital circuits is going to implement to the advanced TCA frame or something new.



- Heterodyne technique is used.
  - IF frequency is tentatively selected to be 10.17 MHz (= 508.58 MHz / 50).
- Direct digital synthesizer (DDS) is employed to generate the IF signal.
- IF signal is directly sampled by a high-speed ADC (498.41 MSPS).

Summary

- I introduced under going plans and a future plan at SPring-8, Especially SPring-8 II. However this plan is still a conceptual design stage.

- The LLRF system for SPring-8 II is also a conceptual design stage. The system concept will be change by future research.